Running head: Eye Movement Patterns and Language Ability

Abstract

Background: Although all intellectually high-functioning children with Autism Spectrum Disorder (ASD) display core social and communication deficits, some develop language within a normative timescale and others experience significant delays and subsequent language impairment. Early attention to social stimuli plays an important role in the emergence of language, and reduced attention to faces has been documented in infants later diagnosed with ASD. We investigated the extent to which patterns of attention to social stimuli would differentiate early and late language onset groups. **Method:** Children with ASD (mean age 10 years) differing on language onset timing (late/normal) and a typically developing (TD) comparison group, completed a task in which visual attention to interacting and non-interacting human figures was mapped using eye tracking. Correlations on visual attention data and results from tests measuring current social and language ability were conducted. **Results:** Patterns of visual attention did not distinguish TD children and ASD children with normal language onset. Children with ASD and late language onset showed significantly reduced attention to salient social stimuli. Associations between current language ability and social attention were observed. **Conclusions:** Delay in language onset is associated with current language skills as well as with specific eye-tracking patterns.

DSM-IV-TR (2000) provided diagnostic criteria for the cluster of disabilities comprising autism spectrum disorders (ASD). However, heterogeneity in the expression and severity of core social and communication deficits, both within and across these sub-group clusters, has posed significant challenges for those attempting to identify their etiology and development. One striking example of variability amongst individuals with a diagnosis of ASD is in the extent that language onset and language competence is disturbed. There has been considerable discussion about whether Asperger syndrome (AS), the ASD subcategory for which significantly delayed language onset is not specified, should be retained in DSM-V. A much cited reason for removing AS from DSM-V was that marked differences distinguishing those with AS and high-functioning autism at early stages of development may lessen over time (Howlin, 2003). However, an intriguing question, given universal deficits in social and communication skills in ASD, is why some individuals with normative IQ levels do not experience marked delays in language onset and development while others do. Neuroconstructivist models of development (e.g. Karmiloff-Smith, 2009) propose that diverse behavioural abnormalities, characteristic in many neurodevelopmental disorders, may in part originate from basic sensory or attentional abnormalities present in early infancy. Given this premise, an important research goal should be to determine which factors contribute to the pattern of heterogeneity in language onset and subsequent language development in ASD.

In typical development, basic attentional mechanisms are thought to orientate the infant towards faces and voices, allowing for the maturation of the social brain and the development of language (Johnson, Dziurawiec, Ellis, & Morton, 1991; Nelson, de Haan, & Thomas, 2006; Pascalis, de Haan, & Nelson, 2002). Social deficit models of development (Dawson et al., 2004; Klin, Jones, Schultz, & Volkmar, 2005; Morton & Johnson, 1991) propose that early reduced exposure to social stimuli leads to delayed and/or atypical development in areas related to social adaptation and language skills. This reduced exposure may result from an impoverished social environment, as evidenced in studies of institutionalised infants (Rutter et al., 1999) or from the infant's own inability to attend selectively to relevant social stimuli. For example, children born blind have been shown to manifest both language and social delays in early childhood (Tadić, Pring, & Dale, 2010) and atypical patterns of face processing have been observed in adults born with congenital cataracts that were surgically removed during the first year of life (Le Grand, Mondloch, Maurer, & Brent, 2001; Mondloch, Le Grand, Maurer, Pascalis, & Slater, 2003). Institutionalised sighted infants who are deprived of social contact display social deficits (Rutter et al., 1999) and early face processing abnormalities have been recorded in such children (Moulson, Westerlund, Fox, Zeanah, & Nelson, 2009). Taken together these studies suggest that impoverished social interactions, at an early stage of development, are associated with the types of social and communication deficits observed in ASD.

The findings from several studies show that individuals with ASD manifest atypical patterns of social orienting (Pelphrey et al., 2002; Senju, Tojo, Dairoku, & Hasegawa, 2004; Volkmar & Mayes, 1990), and it has been suggested that these may be particularly pronounced at the early stages of development (Chawarska, Klin, & Volkmar, 2003; Dawson et al., 2004; Elsabbagh et al., 2013; Elsabbagh et al., 2012; Maestro et al., 2005). Abnormalities in visual fixations and dwell patterns to social stimuli have been observed in adolescents and adults with ASD. For example, in an eye-tracking study in which adolescents and young adults with ASD viewed a scene from the film “Who's Afraid of Virginia Woolf? ” a high number of fixations to the body rather than to the head regions of the actors was observed (Klin, Jones, Schultz, Volkmar, & Cohen, 2002). When fixations were made to the head, they were directed to the mouth rather than the eyes, and this pattern of fixation was positively associated with social skills. Norbury et al. (2009) used a similar eye-tracking paradigm to investigate social attention in teenagers with ASD, and they found that patterns of fixation were specifically associated with language phenotypes. These results, showing that typical patterns of attention to the eye region were associated with language impairment, rather than with age-appropriate language skills, raise important questions about the consequences of atypical social attention in ASD.

The study reported in this paper also used an eye-tracking methodology to test the hypothesis that social attention in ASD would be associated with language ability and social adaptation in childhood. However, the main aims of this study differ from those of previous eye-tracking studies in several ways. Here we investigated visual attention to interacting and non-interacting groupings in perceptually matched competing static stimuli in children with ASD with and without a history of language delay. Thus rather than addressing questions about the salience of specific facial features, or object versus human preferences, we aimed to determine whether or not an interacting grouping would elicit more attention than a non-interacting grouping and whether this would vary over different language phenotypes. In daily life people are encountered in any number of settings and situations, and our ability to understand their attitudes and intentions greatly relies on the extent that we can allocate visual attention to specific relevant cues. Studies investigating low-level visual attention have demonstrated that paired objects containing related properties elicit attention (Gilchrist, Humphreys, & Riddoch, 1996). Working from this basis, we investigated whether the pairing of social objects would also elicit increased saliency. We reasoned that an image of two people facing each other would be perceived as a pair and that this effect would be lessened when the people stood with their backs towards each other. Data from a pilot study testing this new paradigm with neurotypical adults, showing increased viewing time in response to interacting over non-interacting figures, are described in the methods section.

A main aim of our study was to draw links between atypical attention to social stimuli and early language history, and we sub-grouped our ASD participants based on language onset age, whilst closely matching our two groups for chronological age, symptom severity and non-verbal intelligence. For simplicity, our participants are described as high-functioning autism with language delay (HFA-LD) and high-functioning autism with normal language onset (HFA-LN). Language and social attention are strongly linked at early stages of development in typical infants, and atypical patterns of attention have been associated with social and communication impairments in ASD. We therefore hypothesised that the HFA-LN group would spend longer looking at the human figures, and the head region of the figures, than the HFA-LD group. We further hypothesised that when given a choice between interacting and non-interacting human figures, HFA-LN participants would look longer at the more socially salient interacting figures and would show a stronger preference for them than would HFA-LD participants. Our final prediction was that time spent viewing the interacting figures would be negatively associated with social deficits in the ASD sample as a whole, and positively associated with current language competence.

Method

Pilot Study

For the pilot, 23 adult participants participated (male = 9, female = 13). This group had no history or cognitive or language delay and an average age of 22 years (SD = 5, range 18 years – 39 years).

Apparatus

Participants sat on a chair that could be adjusted for height, which was placed at a distance of approximately 1 m from the display screen. Stimuli were displayed on a 21-in computer CRT monitor with each display comprising 800 by 600 pixels. Movements of the left eye were recorded with a sample rate of 500 Hz using a head mounted Eye-Link II tracking device (SR Research).

Stimulus material

Stimulus materials were created from photographs of real people transformed using Photoshop software to produce colour images of cartoon-like figures that displayed on a grey background. It was hoped that these images would be appealing to children. Previous research has demonstrated that children with ASD spend longer looking at cartoon-like figures than objects (van der Geest, Kemner, Camfferman, Verbaten, & van Engeland, 2002). Each stimulus contained two pairs of these cartoon-like figures, one pair standing face-to-face and the other back-to-back. The average height of a figure measured 4.1° of visual angle, and an example stimulus is shown in Figure 1.

Figure 1 around here

There was an equal probability, in any stimulus, of a figure pair, in either of the two configurations, occurring in any of the four quadrants of the screen. The only constraint was that the two pairs presented in any stimulus occurred in diagonally opposite quadrants. There were 60 trials, in which a set of 30 stimuli was presented twice. In the second presentation, the sets of figures appeared in different quadrants to the first.

Procedure

Before beginning the pilot study, each participant's eye movements were calibrated using a nine-point calibration procedure (EyeLink II). As specific viewing instructions have been shown to influence looking patterns in eye-tracking studies (Birmingham, Bischof, & Kingstone, 2008), participants were told that they would be presented with images of people that they were free to look at as they wished. Each stimulus was presented for 10 seconds.

Pilot Study results

Scores were calculated for fixations to whole figures in face-to-face and back-to-back configurations. We also analysed fixations to the head and shoulder areas of the two figures in each of these configurations. Table 1 shows average 'dwell time', defined here as the cumulative duration of all fixations within the ten-second interval for each area of interest for the adult participants.

Place Table 1 around here

Paired sample t-tests revealed that the adult participants looked significantly longer at the face-to-face figures than at the back-to-back figures $t(22) = 3.83$, $p < .001$, d = 1.40. A similar pattern of results was noted when only the head region of the figures were analysed. The adult participants looked significantly longer at the face-to-face head regions than at the back-to-back head regions $t(22) = 4.41$, $p < .001$, d = 0.93. For neurotypical adults, the face-to-face figures proved to be more salient, and were viewed for longer, than the back-to-back figures. The effect size was large, suggesting the need for eight participants per group in order to achieve power of .80.

Experimental Study

Participants

The participant groups in the experimental study included 23 children with a diagnosis of ASD and 16 typically developing (TD) children. All were recruited from local schools and through ASD support groups in South London, UK. The clinical participants had all previously received a diagnosis from a trained clinician, and their language histories were verified with reference to baby books in which their language onset histories had been documented. Criteria for inclusion in the HFA-LN group included a prior diagnosis of ASD with no language delay by a trained clinician, which was then confirmed using the 3di (Skuse et al., 2004). This meant that the participants in this group had used single words before the age of 24-months and phrase speech before the age of 36-months. The participants in the HFA-LD group had received a prior diagnosis of Autism Disorder, and this was confirmed using the 3di. In total, 12 children met the criteria for HFA-LD and 11 children met the criteria for HFA-LN. Age and non-verbal IQ, measured by the Raven's Progressive Matrices (RPM; (Raven, 1941), were used as matching criteria for the three groups. The HFA-LD and HFA-LN groups were further matched on symptom severity, assessed using the 3di. The socialization composite score from the Vineland Adaptive Behavior Scales (VABS (Sparrow & Cicchetti, 1985) was used to investigate associations between social skills and measures on the social attention task. The British Vocabulary Picture Scale-II (BPVS) (Dunn, Dunn, Whetton, & Burley, 1997) and the Communication composite of the VABS (which is a composite score of receptive, expressive and written socially orientated language skills) were used to assess whether or not performance in the experimental tasks would be associated with current levels of receptive language used within a social domain. Relevant psychometric data are shown in Table 2.

Measures

The developmental, dimensional and diagnostic interview (3di). The 3di (Skuse, et al., 2004) is a computer based diagnostic tool increasingly used to diagnose cases of ASD. Outcome measures on the 3di correlate highly with the Autism Diagnostic Interview (Lord, Rutter, & Le Couteur, 1994) equivalent scores. It achieves an inter-rater reliability of 0.9 and a test-retest reliability of 0.9.

The Vineland Adaptive Behavior Scales (VABS). The VABS (Sparrow & Cicchetti, 1985) is a parent administered questionnaire used to assess children and adults on a range of practical social tasks. The VABS has been extensively used to compare behavioural measures of social functioning in autism and other developmental disorders (Volkmar & Mayes, 1990; Wishart, Cebula, Willis, & Pitcairn, 2007).

The British Vocabulary Picture Scale-II (BPVS). The BPVS-II (Dunn et al., 1997) assesses receptive vocabulary through verbal comprehension and provides a measure of verbal mental age. It is a commonly used tool to determine intelligence in autism research (Mottron, 2004). Scores on the BPVS-II are highly correlated with mental age and IQ derived from the Wechsler Intelligence Scale (BPVS-II manual, p. 35-36; Dunn, Dunn, Whetton, & Burley, 1997).

The Raven's Progressive Matrices (Raven, 1941). The RPM assess non-verbal cognitive ability through a set of tasks in which the participant completes the missing part of a puzzle. The RPM is commonly used to test nonverbal cognitive ability in autism (Mottron, 2004).

Place Table 2 around here

Experimental study results

ANOVA Analyses

In order to check for any general abnormalities in gaze control, data for the mean number, and duration, of fixations and saccades is presented in Table 3. There was no significant difference between the three groups on any of these measures suggesting that that the groups displayed similar ocular control when viewing the experimental stimuli.

Table 3 shows average ‘dwell time’, defined here as the cumulative duration of all fixations within the ten-second interval for each area of interest identified in the pilot study. Dwell time was then analysed using a 2x3 mixed analysis of variance (ANOVA) with Configuration (face-to-face v. back-to-back) as the within-group factor and Group (HFA-LD, HFA-LN, TD) as the between-group factor. Data were normally distrusted and assumptions for ANOVA were met.

Table 3 here

Analysis of the whole figures

With respect to dwell time for the whole figures, irrespective of their configuration, the main effect of Group was significant $F(1,36) = 11.97$, $p < .01$, $\eta^2 = .40$. This effect is qualified by a significant Group x Configuration interaction reported below. The main effect of Configuration was significant $F(1,36) = 8.69$, $p < .01$, $\eta^2 = .19$ with the face-to-face figures receiving longer dwell times (M = 3578 ms) than the back-to-back figures (M = 3348 ms). This result further supported our pilot study in showing that interacting human figures elicit longer viewing times than non-interacting figures.

There was a significant Group x Configuration effect $F(2,36) = 4.02$, $p < .05$, $\eta^2 = .18$. Figure 2(a) clearly shows that the interaction reflects a difference in the length of time the groups spent viewing the interacting figures. In relation to dwell times for the back-to-back figures, there was no significant difference between the three groups. However, there was a significant difference in dwell time to the face-to-face figures $F(2,36) = 15.04$, $p < .001$, $\eta^2 = .46$. Simple comparisons revealed that the TD group looked significantly longer at the face-to-face figures than the HFA-LD group ($p < .01$). This result was repeated when the HFA-LD group was compared with the HFA-LN group ($p < .001$). There was no significant difference between the TD and HFA-LN group. Figure 2(a) suggests that whilst the TD and HFA-LN groups spent more time looking at the interacting figures than the back-to-back figures, the HFA-LD group showed the reverse pattern.

Within group comparisons using Bonferroni corrections showed that there was no significant difference in time between the two experimental conditions for the TD group ($p = .10$) and the HFL-LD group ($p = .81$) or the HFL-LN group ($p = .06$)

Place Figure 2 around here

Analysis of head region

With respect to dwell time for the head region of the figures, the main effect of Group was not significant. This result did not support our hypothesis that the TD and HFA-LN groups would spend more time viewing the head region than the HFA-LD group. The main effect of

Configuration was significant $F(1,36) = 8.14$, $p < .01$, $\eta^2 = .19$ with the head region of face-to-face figures receiving longer dwell times (M = 1526 ms) than that of the back-to-back figures (M = 1430 ms). There was a significant Group x Configuration effect $F(1,36) = 6.92$, $p < .01$, $\eta^2 = .28$. Similar to the results for the whole figures, only the face-to-face orientation differentiated the groups. Simple comparisons revealed that the TD group looked significantly longer at the face-to-face figures than the HFA-LD group ($p < .05$). This result was repeated when the HFA-LD was compared with the HFA-LN group ($p < .05$). These effects are shown in Figure 3.

Within group comparisons showed that there was a significant difference in time between the two experimental conditions for the TD group ($p = .02$), but comparisons were not significant for the HFL-LD group ($p = .09$) or the HFL-LN group ($p = .22$).

The outcome of the study suggests that the TD and HFA-LN group performed similarly to each other. However, the pattern of the data suggests that the HFA-LN group appear to be overcompensating (when compared to the TD group) through the amount of time spent viewing the interacting figures. Table 3 compares the results in the form of a ratio of time spent viewing the back-to-back figures to time spent viewing the face-to-face figures. There was no significant difference for the figures between the three groups $F(2,39) = 2.94$, $p = .07$. For the faces, there was a significant difference between the three groups, $F(2,39) = 5.75$, $p = .006$. Post hoc test with Bonferroni corrections revealed a significant difference between the TD and HFA-LD groups ($p = .005$) and between the HFA-LN and HFA-LD groups ($p = .01$), but there was no significant difference between the TD and HFA-LN groups ($p = .88$).

Analysis of first fixations

The number of trials on which the first fixation was directed towards the face-to-face figures was analyzed in order to determine if the groups demonstrated a difference in initial attention allocation. A one-way ANOVA demonstrated that there was a significant difference in allocation of the first fixation between the groups $F(2, 36) = 4.58$, $p = .02$. Post hoc analysis showed a significant difference between the HFA-LN and HFA- LD group (p <. 02) but no significant differences between the HFA-LN and TD groups or the HFA-LD and TD groups. The HFA-LN group directed more initial fixations towards the face-to-face figures (M = 32, SD = 3.67) then did the HFA-LD group (M = 28, SD = 3.56).

Correlational Analysis

The small sample size and the number of correlations conducted meant that separate analysis of the HFA-LD and HFA-LN would be of little statistical benefit. Therefore, for the purpose of this analysis, we assumed a continuum model of ASD used in the DSM-V. All results are reported as one-tailed tests. Due to the number of correlations conducted, only those meeting an alpha level of below 0.01 are reported as being statistically significant.

Significant positive correlations were observed between the face-face configuration and receptive vocabulary mental age scores (BPVS (r = .62, $p < .01$). Correlations carried out on the face-to-face configurations of the whole figures and receptive vocabulary mental age scores (BPVS) ($r = .53$, $p < .01$) were statistically significant. We did not find significant correlations between dwell times to the figures and Communication or Socialization scores on the VABS; although dwell time to the face-to-face head configuration and scores on the VABS socialization scale demonstrated a moderate effect size ($r = .51$, $p = .02$). Our hypothesis that time spent viewing the figures would be associated with improved social skills was not fully supported through the correlational analysis, but increased sample size might help confirmation of this preliminary finding. Age and verbal mental age were highly correlated. In order to determine the impact of age on the correlations, a partial correlation was performed controlling for age. In these analyses the VMA correlation with the face-to-face heads was reduced but remained significant for the head region did not reach the .01 alpha value ($r = .51$, $p = .02$) and the body region ($r = .50$, $p < .02$).

Place Table 4 here

Discussion

The main aim of this study was to investigate social attention in groups of ASD children with and without a history of significant language delay. The most striking finding from the study was that both the pattern and duration of attentional allocation to human figures distinguished the two groups of individuals with ASD. Regardless of configuration, the HFA-LD group spent less time viewing the sets of human figures than either the TD or HFA-LN groups. In relation to the configuration of these figures, group differences emerged on time allocated to the face-to-face condition.

Current debate in ASD research focuses on the extent and nature of social deficits in high-functioning individuals. Previous studies have shown that some individuals with ASD demonstrate preferential attention to social stimuli when the stimuli are not dynamic (Sigman, Mundy, Sherman, & Ungerer, 1986; van der Geest et al., 2002; Willemsen-Swinkels, Buitelaar, Weijnen, & van Engeland, 1998). However, these studies typically present participants with a simple discrimination task, namely, object versus person. Such tasks may be too simple for high-functioning individuals with ASD. Indeed Fletcher-Watson, Leekam, Benson, Frank, and Findlay (2009) demonstrated that although adults with ASD preferred viewing people-present to people-absent images their viewing patterns were nevertheless atypical. Our results support and extend previous findings by demonstrating that language ability is associated with specific patterns of social attention in ASD. Our paradigm extends the object-versus-person studies and suggests that social interactions have differing levels of saliency for viewers. In this respect, language-related differences in attention to social stimuli, in intellectually able individuals with

ASD, may only become apparent when the saliency of competing social objects is the main component of analysis.

Our results, showing that patterns of visual attention are associated with language history, are consistent with those of Norbury et al. (2009). In response to their findings, showing that preserved language skills were not associated with attention to eyes, Norbury et al. proposed that an integration of different social cues might be more important in supporting communication than a reliance on one social cue, for example, the eyes. Further work suggests that social attention in autism may be intricately related to cognitive profiles with verbally able children relying on different social cues than less able children (Rice, Moriuchi, Jones, & Klin, 2012). Our paradigm utilised positioning (interacting or non-interacting) as the primary social cue, and our results showed an association between good language skills and increased attention to the most socially salient configurations. Whilst strong conclusions about the causal relationship between attention and language development cannot be made on the basis of the current study, the results are consistent with the view that patterns of attention to social stimuli continue to be associated with language development beyond infancy (Dawson et al., 2004; Klin et al., 2005; Morton & Johnson, 1991). Whilst language onset history may have small effects in adulthood in ASD (see Howlin 2003), our findings suggest that language delay is associated with language skills and patterns of attention in childhood.

Across our ASD groups, we observed a positive correlation between verbal mental age and time spent viewing the interacting figures but no such correlation was observed with the back-to-back figures. Inflexible or arbitrarily increased allocation of attention to any social stimuli would not be an effective way to gain pertinent social information. Indeed research shows that social saliency serves to direct attention in neurotypical adults (Crosby, Monin, &

Richardson, 2008). Our study demonstrates that some children with ASD are capable of making these types of discrimination when shown simple examples of social situations and that this ability is associated with language competency. An interesting observation from the study was that the HFA-LN group viewed the interacting figures (as compared to the back-to back figures) proportionally longer than the TD group; although this comparison was not statistically significant. One theory for these results is that individuals with ASD who show milder language deficits may need to overcompensate for their social deficits in order to improve language performance. Such overcompensation has also been noted in siblings of children with ASD (Belmonte, Gomot, & Baron-Cohen, 2010).

We have argued that the social saliency of the interacting figures was not recognised by the HFA-LD group. Recent research has suggested that time spent viewing social stimuli is positively associated with arousal (Dalton et al., 2005) and that social stimuli may be less arousing for ASD children with a history of significant language delay (Stagg, Davis, & Heaton, 2013). Interpreted within a developmental framework (Dawson et al., 2005) our results are consistent with the suggestion that some infants with ASD may not find faces stimulating and may fail to develop brain circuitry that enhances the rewarding nature of social stimuli. A more parsimonious explanation of attentional difficulties characterising ASD is offered by the Enhanced Perceptual Functioning Model (EPF: (Mottron & Burack, 2001; Mottron, Dawson, Soulières, Hubert, & Burack, 2006)). According to this model, the low-level perceptual qualities of our stimuli may have increased salience for some individuals with ASD, and this may limit the extent to which these individuals would attend to the 'story' depicted in the visual image. In our study, attentional control may have been guided by bottom up processes in HFA-LD group. In support of this interpretation are results showing that language delayed individuals with ASD demonstrate enhanced perceptual functioning, for example, superior pure-tone pitch discrimination (Bonnel et al., 2010) and superior frequency discrimination skills (Jones et al., 2009). If this interpretation is correct, our stimuli may act as a visual analogue to auditory tasks that are able to discriminate late and typical language onset in ASD.

The results from our study and that of Norbury et al. suggest that attention to the face region and to salient social configurations are associated with language skills in individuals with ASD. Taken together, these studies suggest that there may be two distinct elements related to social attention and language development. First, attention to the invariant features of the face such as the mouth region may serve very specific functions in language development, such as phoneme discrimination. Here, inattention to faces would directly result in delayed acquisition of this aspect of language. Second, as Klin et al. (2002) proposed, individuals need to embed communication within a social framework. Thus, for individuals with ASD who demonstrate reduced attention to socially relevant information, communication will not become socially contextualized. In our study, language skills correlated with increased attention to the socially relevant parts of scenes rather than increased attention to the head region, or the figures in general, and this suggests that for the ASD participants without language delay, communication is more socially contextualized.

It may then be expected that improved social attention skills would relate to a general advantage in social competency. Similarly to Norbury et al., we did not find strong evidence for an association between dwell times and scores on the VABS socialization scale. These results may be due to the relatively small sample size used in our study. In studies that have found a relationship between looking patterns and social ability, language and social context have been highly salient in the stimuli (e.g., Klin et al., 2002). In contrast, our stimuli specifically depicted social and non-social interactions and we analysed gross looking patterns rather than fixation to finer details such as the mouth and eye regions.

Limitations

Sample size was small, and this limits the extent to which the results can be generalised to the wider ASD population. However, as pilot data indicated that we needed a minimum of eight participants to achieve a power of .80, we are confident that our null results can be interpreted with some degree of confidence. In order to hold the attention of the child participants, we manipulated the stimuli in Photoshop to make them more cartoon like. Whilst this reduced naturalistic elements from the stimuli, they retained their social characteristics. Many studies have utilised artificial and schematic social stimuli (Kuhn et al., 2010; Ristic, Friesen, & Kingstone, 2002; Ruffman, Garnham, & Rideout, 2001), and these would appear to be processed in a similar manner to real life social stimuli (Britton, Shin, Barrett, Rauch, & Wright, 2008; Miall, Gowen, & Tchalenko, 2009). The next step will be to replace the figures with actors embedded within social situations. In respect to the groups used in this study, they were matched on symptom severity, and non-verbal intelligence; however, they differed significantly on verbal mental age scores. Despite this difference, the HFA-LD group's receptive language was at an age appropriate level. A positive association between current language skills and language onset history has been demonstrated in a number of studies employing larger sample sizes (Koyama et al., 2004; Szatmari et al., 2009), and our results both confirm such an association and highlight the value of including both language onset and current language in research designs.

Conclusion

The study reported in this paper demonstrated an association between language onset timing, current language skills and patterns of social attention in children with ASD. Whilst current criteria used for subtyping ASDs has not been retained in the DSM-V, our results show that individuals with and without a history of significant language delay can be distinguished on the basis of their attentional deficits in childhood. Current research would appear to confirm that attentional abnormalities are present within the first year of development (Elsabbagh et al., 2013), and our results suggest that they persist into late childhood and are associated with language development. Thus while the DSM-V offers a more unified definition of autism spectrum disorder, it would be a concern if the causes and correlates of delayed language development were not fully investigated. Indeed advances in this area of research may increase our understanding of the extraordinary heterogeneity characterising ASD. The question of whether a continued association, after infancy, between patterns of social attention and language development is specific to ASD or generalises to other types of language delay is an interesting question that warrants further investigation.

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Table 1

Pilot study results (units expressed in milliseconds)

	face-to-face	back-to back
Whole figures	4610 (658)	3750 (576)
Head region	2484 (720)	1912 (485)

Table 2

Matching criteria and language scores with standard deviations in brackets

	TD n=16	HFA-LD n=12	HFA-LN n=11	
Age	9.9 (2.2)	9.6 (1.9)	10 (1.6)	
Raven's percentiles	65 (25)	66 (22.4)	52 (28)	
BPVS verbal mental age	11.9 (3.13)	9.7 (1.7)	12.3(3.3)	HFA-LD < HFA-LN *
3di				
Reciprocal social interaction skills		18.6 (4.8)	16.2(4)	
Social expressiveness		2.3 (1)	2 (1.1)	
Use of language and other social		17.6 (3.1)	15.2 (3.6)	
Use of gesture and non-verbal play		9.5 (2.6)	8.8 (2.8)	
Repetitive/Stereotyped Behaviours and		5.5 (1.9)	4.8 (2.2)	
Age of first word		29 mo (9.62)	14 mo (4.62)	HFA-LD > HFA-LN**
Age of phrase speech		40 mo (10)	18 mo (5.88)	HFA-LD > HFA-LN **
Age of parental concern (years)		1.05 (2.17)	3 (1.42)	HFA-LD <HFA-LN *
Age of diagnosis (years)		5.15 (2.41)	7.71 (1.90)	HFA-LD <HFA-LN *
VABS				
Socialization		62 (8.68)	71 (9.78)	HFA-LD <HFA-LN *
Communication		75 (7.52)	80 (9.19)	

* p = <.05
***p = < .001*

Table 3

Details of eye movement data for the three groups

	TD	HFA-LD	HFA-LN	F	P
Mean duration of a fixation (ms)	422 (139)	374 (92)	399 (103)	.65	.53
Mean number of fixations	22 (4)	19 (3)	22 (5)	.46	.64
Mean number of saccades	24 (3)	26 (4)	25 (5)	.49	.61
Face-to-face figures (ms)	3678 (524)	2965 (421)	4101 (556)	15.05	< .001
Back-to-back figures (ms)	3484 (399)	2996 (516)	3535 (581)	1.90	.16
Face-to-face heads (ms)	1683 (436)	1165 (340)	1691 (536)	4.90	.01
Back-to-back heads (ms)	1538 (428)	1262 (390)	1305 (644)	1.02	.38
Ratios					
back-to back : face to face figures	1 : 1.06	1 : 0.95	1 : 1.16	2.94	.07
back-to back : face to face heads	1 : 1.09	1 : 0.93	1 : 1.29	5.75	<.01

Table 4

Intercorrelations between dwell time and measures of age, socialization, current language levels and language onset for the combined ASD group

	BPVS-VMA	Age of first word	VABS-Socialization	VABS-Communication	Figures (F-F)	Figures (B-B)	Head (F-F)	Head B-B)
Age	.60**	-.06	.01	-.30	.26	.34	.33	.21
BPVS-VMA		-.38	.47	.08	.53**	.23	.62**	.19
Age of first word			-.64*	-.39	-.29	-.20	-.40	-.03
VABS Socialization				.61**	.38	.28	.51*	-.19
VABS-Communication					-.10	-.01	-.13	-.14

Figure Captions

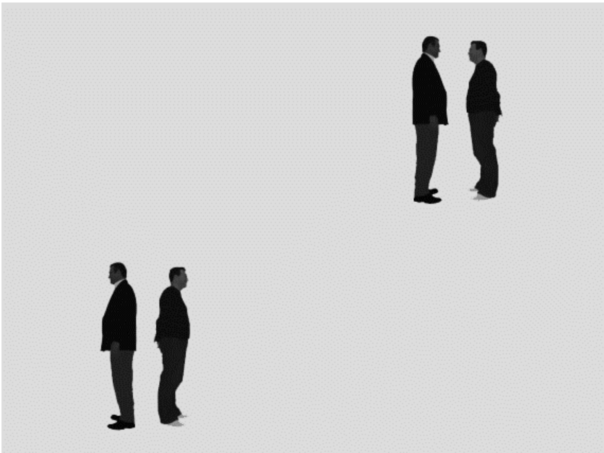
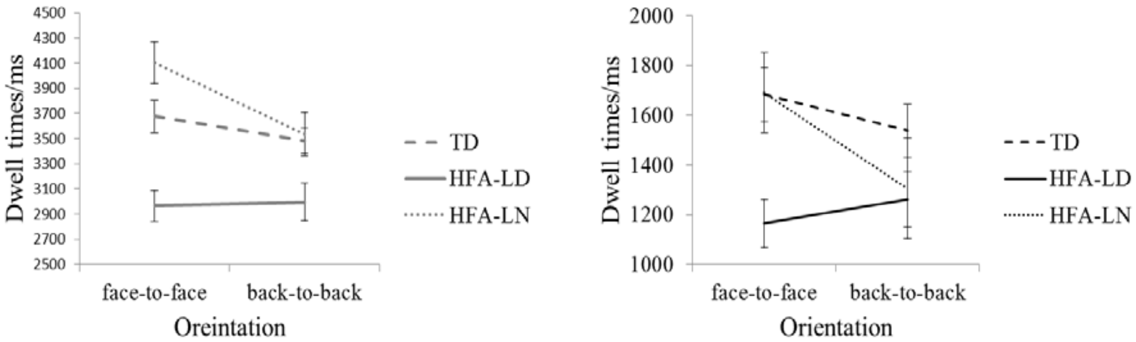


Figure 1 Example of experimental stimuli (originally presented in colour)



(a) (b)

Fig. 2. (a) Dwell times in milliseconds and standard error of the means (SEM) to the human figures for the HFA-LN, HFA-LD and TD groups. (b) Dwell times in milliseconds and SEM to the head regions of the figures for the HFA-LN, HFA-LD and TD groups